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GROUND WATER QUALITY ANALYSIS OF HIREHALLA WATERSHED, KARNATAKA, INDIA USING GIS

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ABSTRACT

This research work is carried out to study ground water quality of the Hirehalla watershed of Koppal district, Karnataka, India. The ground water quality has been analyzed in the laboratory as per standard methods recommended by the Bureau of Indian Standard (BIS) for drinking water. The samples were collected from 43 villages across the watershed in such a way that they represent the entire watershed. The toposheets of the Hirehalla watershed have been used for digitization work using ArcGIS-10.1 software. The Water Quality Indexing (WQI) is done for the study area using important water quality parameters. Ground water quality parameters have been integrated to generate thematic maps showing spatial distribution of various water quality parameters using Inverse Distance Weighed (IWD) spatial interpolation technique with Arc GIS10.1 software. The WQI depicts about 25 villages (58.13%) are having good samples, 1 village (2.32%) is having very good sample and 17 villages (39.53%) are having samples unfit for potability out of 43 village.

KEYWORDS: Watershed, Water Quality Index (WQI), Spatial Distribution, Potable Index, GIS

INTRODUCTION

Water is the most valuable and vital resource for sustenance of life and also for any developmental activity. The groundwater resource should be evaluated thoroughly, carefully and reliably on a real time basis to meet the ever growing needs[1]. Water has become scarce in many parts of the world due to increased needs. The situation is aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental degradation. This freshwater crisis is already evident in many parts of India, varying in scale and intensity depending mainly on the time of the year. According to WHO organization, about 80% of all the diseases in human beings are water borne. Further the groundwater and the pollutants it may carry move with such a low velocity that it may take considerable time for the contaminants to move away from the source of pollution and degradation in the groundwater quality may remain undetected for years. Once the groundwater is contaminated, its quality cannot be restored by arresting the pollutants from the source[2].

The purpose of the present study is to estimate the groundwater quality in the study area and thematically represent it using Geographic Information System (GIS) for understanding of the present scenario at a glance. GIS can be used as a powerful tool for assessing water quality and also to develop solutions for water resources problems on a local or regional scale[3].Groundwater is extensively used for domestic, industrial and irrigation activities. Water quality analysis is one of the most important issues in groundwater studies and its monitoring and assessment is imperative for devising preventive measures against health hazards. Quality of groundwater is equally important to its quantity owing to the

suitability of water for various purposes. Variation of groundwater quality in an area is a function of physico-chemical parameters. Water Quality Index (WQI) provides a single number that expresses overall water quality at certain location, based on several water quality parameters[4] is one of the most effective tools to communicate information on overall quality status of water, to the concerned user community and policy makers[5].

STUDY AREA

The study area is a watershed of Hirehalla which is in Koppal district of Karanataka, India. It is situated in the south western part of Koppal district (76^0 9'11'' to 76^0 46'5" East Longitude and $15^0$29'38" to $15^0$49'5" Latitude), which cover parts of Gangavathi, Kustagi, Sindhanur, Yelburga and Koppaltalukas in Karanataka. The extent of area covered is 681 sqKms. Watershed is delinated using the Survey of India toposheets bearing numbers 57A/1, A/2, A/5, A/6, A/10 and A/11. This area is well connected by National Highway 13. It experiences severe droughts frequently with weather of 30-40^0 C temperature. More than 65 percent of the population sustains on agro-based economy.

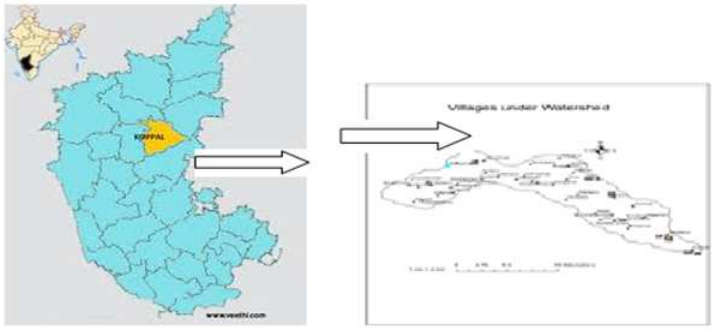


Figure 1: Location Map of the Study Area

MATERIALS AND METHODS

Data Collection

Watershed delineation has been done using Survey of India topomaps, then, the bore wells in the study area were selected and GPS is used to locate all the sampling points. The water samples were collected by grab and composite sampling method. Co-ordinates of sampling stations are shown in table no.1. These sampling stations were among the open wells and bore wells. For the groundwater sampling stations shape files are created using ARC GIS 10.1. The attribute information was prepared i.e., water quality parameters such as pH, Electrical Conductivity (EC), alkalinity, TDS, Total hardness, Chloride, Fluoride, Sulphate, Calcium and Nitrates and attached to the respective sampling locations.

Table 1: Showing the Details of Water Sampling Stations

Sample Code	Latitude	Longitude	Names of Village
1	15.75611	76.26263	Ganganal
2	15.76567	76.27765	Hiremannapur
3	15.77323	76.32366	Hanchinal
4	15.76053	76.40231	Tavargera
5	15.75733	76.44332	Kalachilmi
6	15.7809	76.45196	Veerapur
7	15.75643	76.46656	Garlote
8	15.73456	76.475	Umlote
9	15.7127	76.46441	Pura
10	15.69292	76.44117	Sanganal
11	15.6989	76.41402	Hiretimmanal
12	15.701	76.40595	Chicktimmanal

Table 1: Contd.,

13	15.60084	76.51225	Wadki
14	15.59804	76.54103	Chirchangudda
15	15.57853	76.52158	Jiral
16	15.57334	76.54414	Chickdankankal
17	15.57733	76.54519	Hiredankankal
18	15.5497	76.56844	Singanal
19	15.48005	76.67826	Kuntoji
20	15.55863	76.57181	Gundur Cross
21	15.52985	76.63473	Siddapur
22	15.58497	76.59228	Tondihal
23	15.58958	76.59713	Hagehal
24	15.62386	76.57663	Somnal
25	15.65128	76.54472	Nauli
26	15.64515	76.46395	Gudadur
27	15.66121	76.48333	Mallapur
28	15.7227	76.39297	Menadhal
29	15.71117	76.36329	Hadagali
30	15.72269	76.34825	Rampur
31	15.73297	76.32576	Hulipur
32	15.71349	76.31984	Gorlahal
33	15.70733	76.30336	Siddlabhavi
34	15.68309	76.29291	Chickmannapur
35	15.68213	76.2674	Vanajabhavi
36	15.66781	76.27142	Markat
37	15.65822	76.24576	Kalbhavi
38	15.6276	76.21218	Uppaladinni
39	15.63813	76.20469	Nilogal
40	15.69011	76.19696	Budukunti
41	15.684	76.21279	Kutakmari
42	15.70995	76.20137	Kurubanhal
43	15.5233	76.23598	Yeddoni

Chemical Analysis

Water samples, in clean polyethylene bottles were collected from 43 boreholes capturing the aquifer depth ranging from 300 feet to 600 feet. Before collecting the samples, bottles were thoroughly rinsed with groundwater to be sampled. In case of bore wells water samples were collected after pumping for 10 minutes. Various parameters such as pH, Electrical Conductivity (EC), TDS, Calcium, Alkalinity, Chloride, Total Hardness, Sulphate, Nitrate and Fluoride were determined using standard procedures recommended by Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR)[6].

Estimation of Water Quality Index

Water Quality Index (WQI) is a very useful and efficient method for assessing the quality of water and also useful tool for communicating the information on overall quality of water. The Water Quality Index (WQI) allows ‘good’ and ‘bad’ water quality to be quantified by reducing a large quantity of data on a range of physic- chemical and biological variables to a single number in a simple, objective and reproducible manner. WQI improves understanding of water quality issues by integrating complex data and generating a score that describes water quality status and evaluates water quality trends. In present study the WQI has been calculated by using standards of drinking water quality recommended by the Bureau of Indian standards (BIS) and Indian Council for Medical Research (ICMR) and weighted index method[5]. In the

present study eight water quality parameters, namely pH, Electrical Conductivity (EC), Alkalinity, TDS, Total hardness, Calcium, Chloride, Sulphate, Nitrate and Fluoride were considered for computing WQI[6]. Water Quality Index (WQI) is calculated using Weighted Arithmetic Index method [6&7].

$$WQI = \sum_{n=1}^{n} qnWn / \sum_{n=1}^{n} Wn \quad (1)$$

Where,

Weightage factor (Wn) is computed using the following equation.

$$W_n = k / Sn \quad (2)$$

Where,

K, Proportionality constant is derived from,

$$K = \left[1 / \left(\sum_{n=1}^{n} 1 / Sn\right)\right] \quad (3)$$

Where,

S_n and S_i are the BIS/ICMR standards values of the water quality parameter.

And Quality rating (q) is calculated using the formula,

$$q_{ni=S} - \quad (4)$$

Where,

q_{ni}= Quality rating of i^{th} parameter for a total of n water quality parameters

V_{actual} = Value of the water quality parameter obtained from laboratory analysis

V_{ideal}= Value of that water quality parameter can be obtained from the standard tables

V_{ideal} for pH = 7 and for other parameters it is equivalent to zero

$V_{standard}$ = BIS / ICMR standard of the water quality parameter

Table 2: Water Quality Parameters, Their ICMAR/BIS Standards and Assigned Unit Weights

Parameter	Standard (S_n& S_i)	$1/S_n$	K	Weightage (W_n)
pH	8.5	0.1176	1.1861	0.1395
EC	300	0.00333	1.1861	0.0005
TDS	500	0.00200	1.1861	0.00237
Total Hardness	300	0.00333	1.1861	0.00395
Calcium	75	0.01333	1.1861	0.015815
Alkalinity	120	0.00833	1.1861	0.009884
Chloride	250	0.004	1.1861	0.0047447
Sulphate	200	0.005	1.1861	0.0059309
Fluoride	1.5	0.66667	1.1861	0.7907965
Nitrate	45	0.02222	1.1861	0.0263571

EC-Electrical Conductivity, TDS-Total Dissolved Solids

Table 3: Water Quality Parameter as Per Laboratory Analysis and WQI

Name of Village	Sample	pH	E. C	TH	Ca^{2-}	Alk	Cl^-	TDS	SO_4^{2-}	NO_3^-	Fl	WQI
Ganganal	1	7.06	2500	568	240	272	168	737	175	43	2.0	117.8279
Hiremannapur	2	6.64	2760	708	300	268	752	1608	365	30	2.0	116.6686
Hanchinal	3	6.59	2040	488	268	480	92	693	77	27	1.3	72.57527
Tavargera	4	6.7	3370	468	250	720	208	1054	255	25	1.4	86.05121
Kalachilmi	5	6.64	1870	248	132	544	88	855	80	20	1.1	64.27065
veerapur	6	6.82	2050	536	184	384	60	610	61	22	0.9	55.45621
Garlote	7	6.92	1790	564	644	404	188	939	133	30	1.8	114.81
Umlote	8	6.82	1080	548	264	304	100	543	66	20	1.2	72.22902
Pura	9	6.86	1690	432	272	484	256	957	108	40	1.1	70.63472
Sanganal	10	6.77	2870	592	186	480	268	1143	175	33	1.8	105.0004
Hiretimmanal	11	6.37	2930	540	316	452	148	1148	161	25	1.3	76.62713
Chicktimmanal	12	6.38	1280	124	138	280	64	667	91	37	2.0	107.9646
Wadki	13	6.42	2190	568	368	360	336	1153	114	5	1.8	102.8542
Chirchangudda	14	7.5	1483	456	127	210	254	972	106	25	1.4	86.23361
Jiral	15	6.91	1650	484	228	316	360	970	128	15	1.3	78.19763
Chickdankankal	16	7.21	1020	196	272	96	36	276	27	5	1.8	104.2366
Hiredankankal	17	6.84	2590	620	628	308	196	1062	304	15	1.8	112.7362
Singanal	18	6.89	3046	224	200	368	112	1836	295	5	1.8	103.7583
Kuntoji	19	6.98	2340	364	192	376	116	706	116	20	1.3	78.11566
Gundur Cross	20	6.74	1920	412	356	268	112	586	147	25	1.2	73.55062
Siddapur	21	7.02	3560	780	442	312	744	1958	358	20	1.4	91.59146
Tondihal	22	6.66	1200	292	340	196	32	381	71	15	1.0	60.09131
Hasehal	23	6.82	1850	276	232	272	68	538	75	10	1.7	96.69277
Somnal	24	7.01	2230	372	336	368	216	1011	248	20	1.8	108.4581
Nauli	25	6.91	4530	260	312	504	156	1460	328	40	1.5	93.75439
Gudadur	26	7.15	2230	192	144	388	44	653	127	15	1.8	104.4914
Mallapur	27	7.19	1240	156	248	262	16	318	31	17	1.8	105.5627
Menadhal	28	6.52	4780	624	424	907	820	2868	328	30	0.9	66.00518
Hadagali	29	7.06	1840	328	312	292	120	528	68	10	1.4	85.10281
Rampur	30	6.86	3340	964	408	560	292	1010	177	25	0.5	42.66629
Hulipur	31	6.5	2880	808	316	268	136	816	336	15	0.9	55.3842
Gorlahal	32	7.1	1670	368	236	480	52	515	65	27	1.1	70.50468
Siddlabhavi	33	7.02	2330	224	216	568	120	662	54	32	1.8	107.2553
Chickmannapur	34	7.9	1512	265	230	510	29	605	73	35	1.6	104.7784
Vanajabhavi	35	7.8	1450	630	190	220	790	810	270	25	1.0	71.00268
Markat	36	7.1	2130	210	170	344	48	1200	132	15	1.6	93.97124
Kalbhavi	37	8.1	1100	690	298	260	680	650	255	20	0.9	70.57531
Uppaladinni	38	7.9	1600	510	190	540	32	610	140	25	1.4	93.58456
Nilogal	39	6.94	2220	336	392	264	100	540	55	30	1.7	102.3811
Budukunti	40	6.36	1623	524	244	328	164	884	75	15	1.9	104.7238
Kutakmari	41	6.84	2130	660	524	552	304	1205	147	26	1.3	86.68513
Kurubanhal	42	6.47	923	380	248	192	76	503	52	26	1.3	82.21462
Yeddoni	43	6.58	1670	509	172	568	148	827	94	25	2.0	112.9744

E. C-Electrical Conductivity, TH-Total Hardness, Alk-Alkalinity, Cl^--Ghlorides, TDS-Total Dissolved Solids, $SO42^{--}$Sulphates, Fl-Flourides and NO^{3--}Nitra

Generation of Thematic Maps

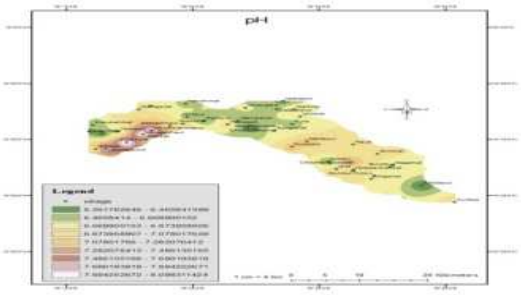
GIS techniques facilitates integration and conjunctive analysis of large volumes of multidisciplinary data both spatial and non – spatial within the same geo-reference. Spatial analysis extension of GIS allows interpolation of the water quality parameter at unknown location from known values to create a continuous surface which will help us to understand the scenarios of water quality parameter of the study area. There are various interpolation techniques such as Inverse Distance weighted (IDW), Spline, Trend surface Analysis and Kriging available in ARC GIS 10.1 Spatial Analysis extension. In the present study Inverse Distance Weightage (IDW) technique adopted to create the spatial distribution maps of water quality parameters and WQI.

RESULTS AND DISCUSSIONS

Spatial distribution of various chemical parametrs within watershed were presented in the form of thematic maps generated using ARC GIS 10.1.

pH

The values of pH in the groundwater samples collected varied from 6.26 to 8.10. This shows that the quality of groundwater in the study area is within desirable limit. Spatial distributions of pH concentrations are shown in Figure 2.



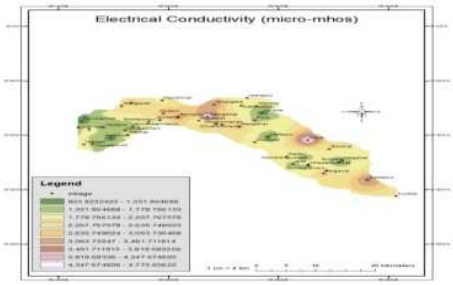


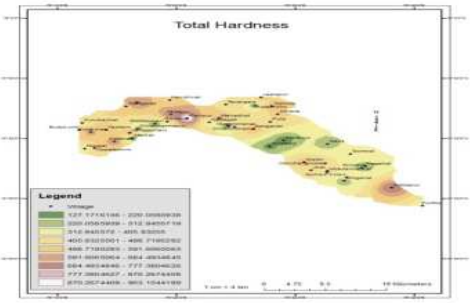
Figure 2: Spatial Distributions of Ph Concentrations Figure 3: Spatial Distribution of Electrical Conductivity

Electrical Conductivity (EC)

In the study area Electrical Conductivity varies from 923. 823 µS/cm to 4775.6525µS/cm. The areas at Nauli, Hadegali, Siddapur and Rampur are having higher Electrical Conductivity exceeding 2000 µmhos/cm. Figure 3 shows spatial distribution of EC. It is observed that higher concentration in the north east part of the study area.

Hardness

Figure 4 Shows the Spatial distribution of the ground water hardness in the study area and it varies from 127.17 mg/l to 963.1544mg/l. Higher concentration of hardness was found in Rampur, Hulipur, Ganganal, Kalbhavi, Kutakmani, Siddapur, Wadki, Chirchangudda and this may be due to natural accumulation of salt.



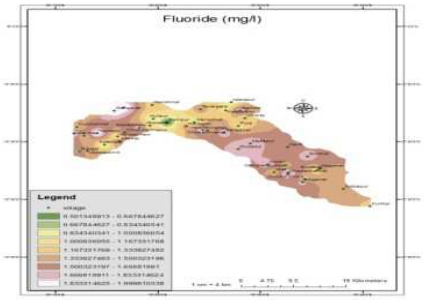


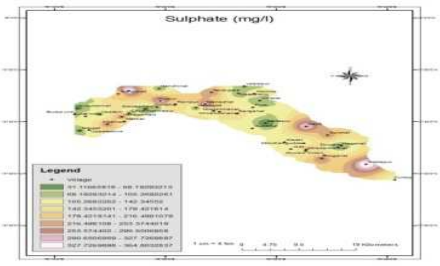
Figure 4: Spatial Distribution of Hardness Figure 5: Spatial Distribution of Fluoride

Fluoride

The concentration of fluoride is below 1 mg/l in most of the villages. The fluoride values are within desirable limit in study area. But in villages Yeddoni, Kutakmani, Chickmannapur, Ganganal, Kalachimi, Hiretimmanal the fluoride concentration is more than 1.5 mg/lit. The figure 5 shows the spatial distribution of fluoride in the study area.

Nitrate

In the entire Hierhalla Watershed the nitrate concentration was found to be below 45 mg/lit. But nitrate concentration was found higher due to the over- application of fertilizer in places at like Navli, Pura, Ganganal. The figure 6 shows spatial distribution and nitrate concentration was higher at the part of north eastern side in the study area. But the Nitrate was found to be within permissible limit throughout the study area.



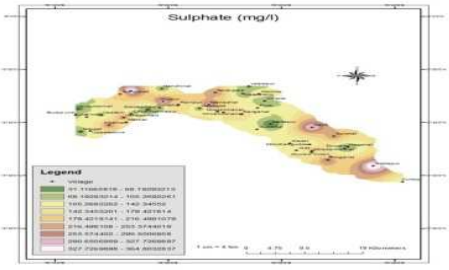


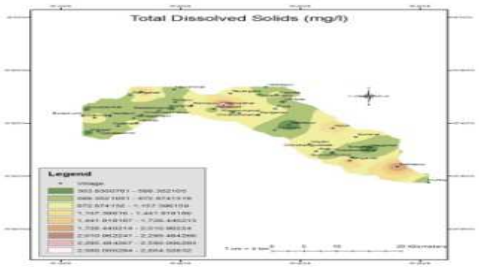
Figure 6: Spatial Distribution of Nitrate **Figure 7: Spatial Distribution of Sulphate**

Sulphate

The figure 7 shows spatial distribution of sulphate in the groundwater in the study area varies between 31.11 to 364.80 mg/l. In the study area the higher sulphate concentration was found at places Siddapur, Navli, Hulipur, Ganganal, Hadagali, Tavargera, kalbhavi and was above 200 mg/l permissible limit.

Total Dissolved Solid (TDS)

Figure 8 shows spatial distribution of TDS in the study area and its range varies from 303.830 to2864.52 mg/l. The high concentration of TDS was observed as 2864.52mg/l at Hadagali. In study area the higher concentration of TDS was found at the places like Siddapur, Market, Tavargera, Ganaganal, Singanal, Wadki, Chicktimmal, Sanganal. These places primarily irrigated fields by Tungabhadra left bank canal. These villages are lying on the southern part of the watershed.



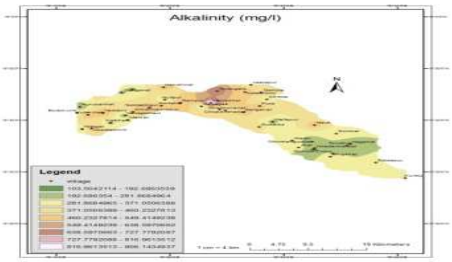


Figure 8: Spatial Distribution of Total Dissolved Solids **Figure 9: Spatial Distribution of Alkalinity**

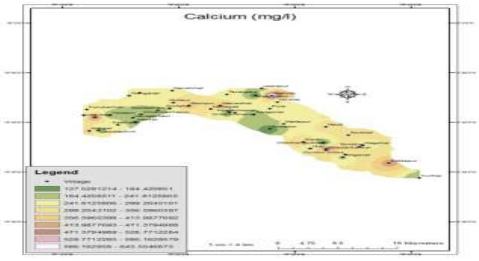
Alkalinity

Figure 9 shows spatial distribution of Total Alkalinity in the groundwater in the study area and its value varies from 103.504 to 906.143 mg/l. Higher alkalinity was observed at the region of Menadhal, Tavargera.

Calcium

Figure 10 Shows the spatial distribution of Calcium in the groundwater of the study area, which ranges from

127.029 to 643.55 mg/l. The high concentration of calcium was found in Katakmani, Siddapur, Garlote, Hiredankankal, Gundur cross, which lies in northern part of the watershed.



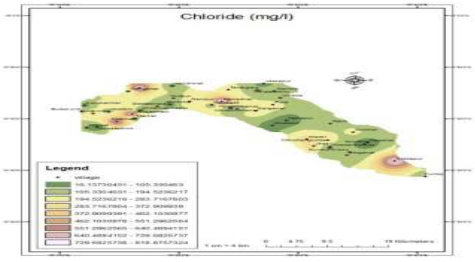


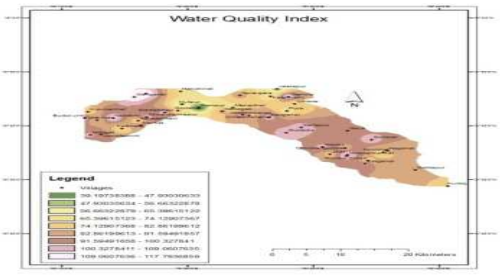
Figure 10: Spatial Distribution of Calcium **Figure 11: Spatial Distribution of Chloride**

Chloride

Figure 11 shows spatial distribution of Chloride in the study area. Its range varies between 16.137 to 818.859mg/l. High concentration of chloride was observed as 818.859 mg/l at region like Siddapur, Hadagali, Ganganal, Kalbhavi, vanajabhavi.

Water Quality Index

The Water Quality Index in the study area of Hirehalla watershed is varying from 39.197 to 117.793. The observation in Figure 12 shows Spatial Distribution WQI has been observed high value in Yeddoni, Sommal, Mallapur, Gudadur, Sanganal, Hiretimmanal, Ganganal and low values of WQI observed in the area of Veerapur and Rampur.



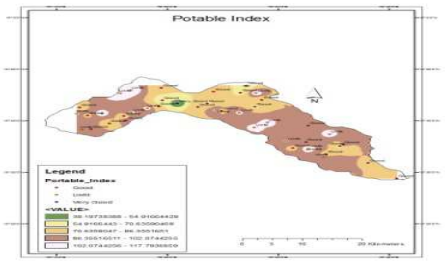


Figure 12: Spatial Distribution of Water Quality Index **Figure 13: Showing Spatial Distribution of Potability Index**

Figure 13 shows the potability Index map of the Hirehalla watershed. It shows spatial distribution of both potable water area and also nonpotable water area.

CONCLUSIONS

The study area has Water Quality Index (WQI) value ranging from 39.197 to 117.793. The spatial distribution map of WQI shows values high in the northern part of the watershed. i. e. Ganganal, Yeddoni and low at Veerapur and Rampur. Potable Index for the study area is depicted by thematic map as Unfit, Good and Very Good with spatial distribution.

The unfit Portable Index is ranging from 100 to 117.82, which is high in the northern and central part of Hirehalla Watershed. Good and very good Potable Index ranges from 0 to 100. According to Potable Index nearly 25 villages (58.13%) are having good samples, 1 village (2.32%) is having very good sample and 17 villages (39.53%) are having

unfit samples of 43 villages. The spatial distribution thematic map of WQI and Potable Index helps us to understand the quality of groundwater and also to develop suitable methods to protect it for the authorities as well as law makers.

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